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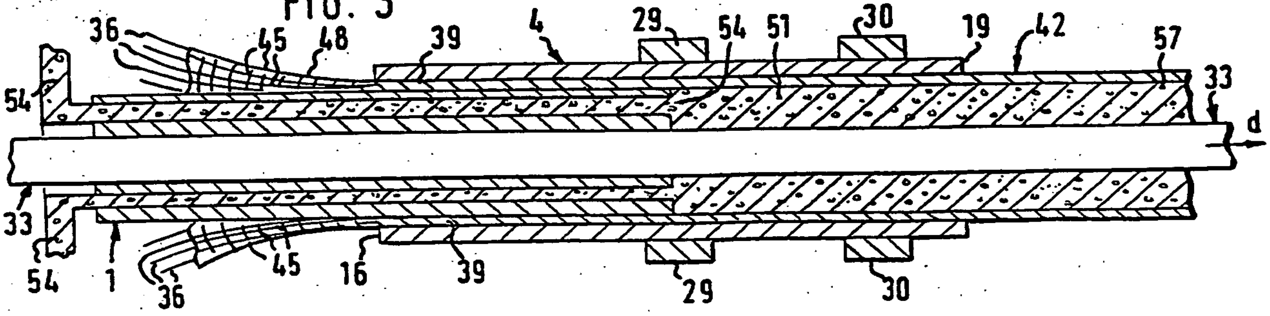
(54) **Method for thermally insulating a pipeline.**

(57) Method for thermally insulating a pipeline (33) along at least part of its length, the method comprising manufacturing a protective sleeve (42) around the pipeline (33) at a selected radial distance therefrom in a die (4) and inducing both the sleeve (42) and the pipeline (33) to move axially at substantially the same speed relative to the die (4) while maintaining an annular space (51) between the sleeve (42) and the pipeline (33). Components for forming a thermal insulation layer are progressively injected in the annular space (51) between the sleeve (42) and the pipeline (33).

FIG. 3



METHOD FOR THERMALLY INSULATING A PIPELINE

The invention relates to a method for thermally insulating a pipeline along at least part of its length. It is known in the art to insulate a pipeline by applying a thermal insulation layer around the pipeline. A subsea pipeline may additionally be provided with a protective sleeve around the thermal insulation layer so as to protect the said layer against damage from hydrostatic pressure. In order to allow the insulated pipeline to be laid by any one of the existing pipelaying methods, the thermal insulation layer and the sleeve should have adequate flexibility.

US patent No. 4 657 050 discloses a method for thermally insulating a pipeline, wherein first a thermal insulation layer is manufactured around the pipeline and whereupon a plastic sleeve of uniform diameter is manufactured around the insulation layer.

In the known method it is required to machine the insulation layer to a uniform outer diameter before manufacturing the plastic sleeve, in order to allow the sleeve to be fitted around the thermal insulation layer.

It is an object of the invention to provide a method for thermally insulating a pipeline wherein an adequate fit of the plastic sleeve around the thermal insulation layer is obtained while eliminating the step of machining the said layer to a uniform diameter.

In accordance with the invention a method for thermally insulating a pipeline along at least part of its length comprises:

- manufacturing a protective sleeve around the pipeline at a selected radial distance therefrom in a die and inducing both the sleeve and the pipeline to move axially at substantially the same speed relative to the die while maintaining an annular space between the sleeve and the pipeline.
- progressively injecting components for forming a thermal insulation layer in the annular space between the sleeve and the pipeline.

The method according to the invention enables manufacturing of an annular thermal insulation layer and a protective sleeve around a pipeline in a single operation and in a continuous manner.

Preferably the components for forming the thermal insulation layer comprise a thermosetting resin, which resin is allowed to cure in the annular space between the sleeve and the pipeline so as to form a thermal insulation layer around the pipeline. An insulation layer made from such a resin has adequate mechanical properties even at elevated temperatures.

It is preferred to inject microspheres into the annular space between the sleeve and the pipeline simultaneously with the thermosetting resin so as to create a syntactic insulation layer having a low thermal conductivity and a high resistance against hydrostatic pressure.

Preferably the step of manufacturing the protective sleeve is carried out simultaneously with the step of progressively injecting the components for forming the thermal insulation layer. In this manner the time required to insulate the pipeline is further reduced.

Preferably the step of manufacturing the protective sleeve comprises supplying a thermosetting resin for forming the sleeve to an annular space between the die and a mandrel extending in the die, allowing the thermosetting resin for forming the sleeve to cure so as to form the sleeve and simultaneously inducing the sleeve to move through the die.

Suitably the step of manufacturing the sleeve further comprises supplying fibres to the annular space between the die and the mandrel simultaneously with the thermosetting resin for forming the sleeve.

The invention will now be explained in more detail with reference to the accompanying drawings, wherein:

Figure 1 shows schematically a longitudinal cross-section of an apparatus for thermally insulating a pipeline by the method according to the invention;

Figure 2 shows cross-section II-II of Figure 1;

Figure 3 shows schematically the apparatus of Figure 1 and a pipeline being thermally insulated by the method according to the invention; and

Figure 4 shows schematically a longitudinal cross-section of an alternative apparatus for thermally insulating a pipeline by the method according to the invention.

Reference is now made to Figures 1 and 2, which show a cylindrical mandrel 1 extending concentrically into a die 4, the die having a larger internal diameter than the outer diameter of the mandrel 1. Thus, an annular space 7 is formed between the outer wall 10 of the mandrel 1 and the inner wall 13 of the die 4. The end of the die 4 through which the mandrel 1 extends is defined as the inlet end 16, and the opposite end of the die 4 is defined as the outlet end 19.

The mandrel 1 is provided with a cylindrical channel 22 arranged concentrically in the mandrel 1, which channel has an internal diameter corresponding to the outer diameter of a pipeline which is to be insulated. Furthermore the mandrel 1 is provided with two feed channels 25,26 extend-

ing parallel to the cylindrical channel 22.

A primary heater 29 and a secondary heater 30 surround the die 4 along part of its length.

Reference is now further made to Figure 3.

During normal operation a pipeline 33 is induced to move axially through the cylindrical channel 22 of the mandrel 1 and through the die 4, in the direction (d) from the inlet end 16 to the outlet end 19.

A thermosetting resin is introduced at the inlet end 16 of the die 4 into the annular space 7 between the die 4 and the mandrel 1. Rovings 36 are introduced into the annular space 7 simultaneously with the thermosetting resin. The thermosetting resin is allowed to adhere to the rovings 36. The thermosetting resin starts to cure in the die 4, thereby forming a protective sleeve 42. The rovings 36 provide stability for the sleeve until curing has taken place.

Reinforcement fibres 45 are supplied to the annular space 7 between the die 4 and the mandrel 1 simultaneously with the thermosetting resin, which fibres 45 are allowed to adhere to the thermosetting resin. The fibres 45 are arranged in the form of a filament mat 48.

The sleeve 42 is pulled at the same speed as the pipeline 33 through the die 4, while an annular space 51 is maintained between the pipeline 33 and the sleeve 42.

A mixture 54 of a polyester resin and hollow glass microspheres is continuously injected through the feed channels 25,26 of the mandrel 1 into the space 51 between the pipeline 33 and the sleeve 42 in which space the polyester resin is allowed to adhere to the outer wall of the pipeline 33 and to the inner wall of the sleeve 42. The polyester resin cures to a syntactic insulation layer 57 of matrix material in which hollow glass microspheres are embedded.

Curing of the polyester resin and the thermosetting resin is accelerated by heating the said resins with the heaters 29,30. The heat provided by the heaters 29,30 is controlled so that the polyester resin and the thermosetting resin are virtually cured by the time these resins leave the die 4.

Figure 4 shows a tapered die construction for use in the method according to the invention. Both the thermosetting resin and the polyester resin may have a tendency to shrink during curing. To reduce the occurrence of thermal cracks and voids in the sleeve 42 and/or the syntactic insulation layer 57 due this tendency of shrinkage a tapered die 58 can be used. This tapered die 58 is similar to the tubular die with reference to Figures 1 and 2, except that the tapered die 58 comprises an intermediate part 60 which is internally tapered. The intermediate part 60 is arranged between an inlet part 63 and an outlet part 66 of smaller internal diameter than the inlet part, and the intermediate part 60 tapers internally from the inner diameter of the inlet part 63 to the inner diameter of the outlet part 66. The mandrel 1 has a smaller outer diameter than the inner diameter of the inlet part 63 of the die 58, which mandrel 1 extends concentrically into the inlet part 63. Thus, an annular space 7 is formed between the inner wall 67 of the inlet part 63 of the die 58 and the outer wall 10 of the mandrel 1.

The tapered die 58 operates substantially similar to the tubular die 4 shown in Figures 1, 2 and 3. However, in use the sleeve 42 moves along the tapered inner wall of the intermediate part 60 of the tapered die 58, and thereby the sleeve 42 and the syntactic insulation layer 57 are radially compressed as at this location of the die 58 the polyester resin and the thermosetting resin have not yet completely cured. This radial compression reduces the occurrence of thermal cracks and voids in the sleeve 42 and the syntactic layer 57.

In the Figures a mandrel is shown with two feed channels. It will be understood that the number of feed channels can also be one or more than two, or that an annular feed channel is applied. In case of more than one feed channel, different components for forming the thermal insulation layer can be supplied through separate feed channels.

In a suitable embodiment of the invention the filament mat of reinforcement fibres is pre-impregnated with the thermosetting resin.

Preferably each thermosetting resin is selected from the group of epoxy, polyester, polyurethane and phenol-formaldehyde resins.

It will be understood that instead of introducing a polyester resin and microspheres into the space between the pipeline and the sleeve also a pure thermosetting, or a resin mixed with a foam generating agent may be introduced into said space.

Instead of introducing a filament mat and a thermosetting resin into the annular space between the die and the mandrel a filament mat only can be introduced into said space, which mat serves to contain the polymer resin between the mat and the pipeline before said resin has cured.

A good bond between the syntactic insulation layer and the pipeline is obtained if the pipeline is provided with an anticorrosion coating, e.g. fusion bonded epoxy, before the syntactic insulation layer is applied. It will be appreciated that the internal diameter of the cylindrical channel of the mandrel through which the pipeline moves should then correspond to the outer diameter of the pipeline including the anticorrosion coating.

EXAMPLE

An experiment has been carried out in which a cylindrical steel sample having an outer diameter of 22 mm was used to simulate the pipeline. The steel sample was provided with a 0.50 mm thick anticorrosion coating of fusion bonded epoxy. The mandrel had an outer diameter of 72 mm, and the die had an internal diameter of 76 mm. In order to account for scale factors in the temperature distribution resulting from heat supplied to the die, a solid rod rather than a tube was used as a steel sample.

Two glass-fibre mats, one outer mat and one inner mat, were used to construct the sleeve. The outer mat was impregnated with polyester resin for forming the sleeve whereas the inner mat was kept dry. The function of the inner mat was to assist in preventing penetration of polyester resin for forming the thermal insulation layer through the sleeve when the polyester resin for forming the sleeve had not yet completely cured.

A syntactic foam comprising a polyester resin and glass microspheres 3M type B37/2000 was injected in the annular space between the steel rod and the sleeve.

To inject the syntactic foam into the space between the steel rod and the sleeve a twin feed system was used. One feed channel carried syntactic foam with resin containing catalyst while the other feed channel carried syntactic foam with accelerator in the resin, a ratio 1:1 being used.

The die had the tubular shape shown in Figures 1 and 2, and was heated to a temperature of 100 °C. The sleeve and the rod were pulled through the die at a rate of 0.15 m/min, while the syntactic foam was pumped through the feed channels at a pressure of 3.1 bar. Under these conditions a 10 m length of rod was successfully coated. Evaluation of the test results revealed that no voids or cracks were present in the syntactic layer, and that a good bond between the syntactic layer and the rod was obtained.

Claims

1. Method for thermally insulating a pipeline along at least part of its length, the method comprising:
- manufacturing a protective sleeve around the pipeline at a selected radial distance therefrom in a die and inducing both the sleeve and the pipeline to move axially at substantially the same speed relative to the die while maintaining an annular space between the sleeve and the pipeline,
- progressively injecting components for forming a thermal insulation layer in the annular space between the sleeve and the pipeline.

2. The method of claim 1, wherein the components for forming the thermal insulation layer comprise a thermosetting resin, which resin is allowed to cure in the annular space between the sleeve and the pipeline so as to form a thermal insulation layer around the pipeline.

3. The method of claim 2, wherein microspheres are injected into the annular space between the sleeve and the pipeline simultaneously with the thermosetting resin.

4. The method of any one of claims 1-3, wherein the step of manufacturing the protective sleeve is carried out simultaneously with the step of progressively injecting the components for forming the thermal insulation layer.

5. The method of any one of claims 1-4, wherein the step of manufacturing the protective sleeve comprises:
- supplying a thermosetting resin for forming the sleeve to an annular space between the die and a mandrel extending in the die;
- allowing the thermosetting resin for forming the sleeve to cure so as to form the sleeve; and
- simultaneously inducing the sleeve to move through the die.

6. The method of claim 5, wherein the step of manufacturing the sleeve further comprises:
- supplying fibres to the annular space between the die and the mandrel simultaneously with the thermosetting resin for forming the sleeve.

7. The method of claim 6, wherein the fibres are arranged in the form of at least one filament mat.

8. The method of claim 7, wherein a filament mat is pre-impregnated with the thermosetting resin for forming the sleeve.

9. The method of any one of claims 2-8, wherein each thermosetting resin is selected from the group of epoxy, polyester, polyurethane and phenol-formaldehyde resins.

10. The method of any one of claims 1-9, wherein the sleeve is induced to move through the die by pulling the sleeve through the die.

11. The method of any one of claims 2-10, wherein the sleeve is induced to move through a tapered die, which die tapers internally to a smaller diameter, seen in the direction of movement of the sleeve.

12. The method of any one of claims 2-11, wherein heat is supplied by a heater which surrounds the die along at least part of its length.

13. The method as described hereinbefore with particular reference to the drawings.

14. A thermally insulated pipeline whenever produced by a method as claimed in any one of claims 1-13 with particular reference to the drawings.

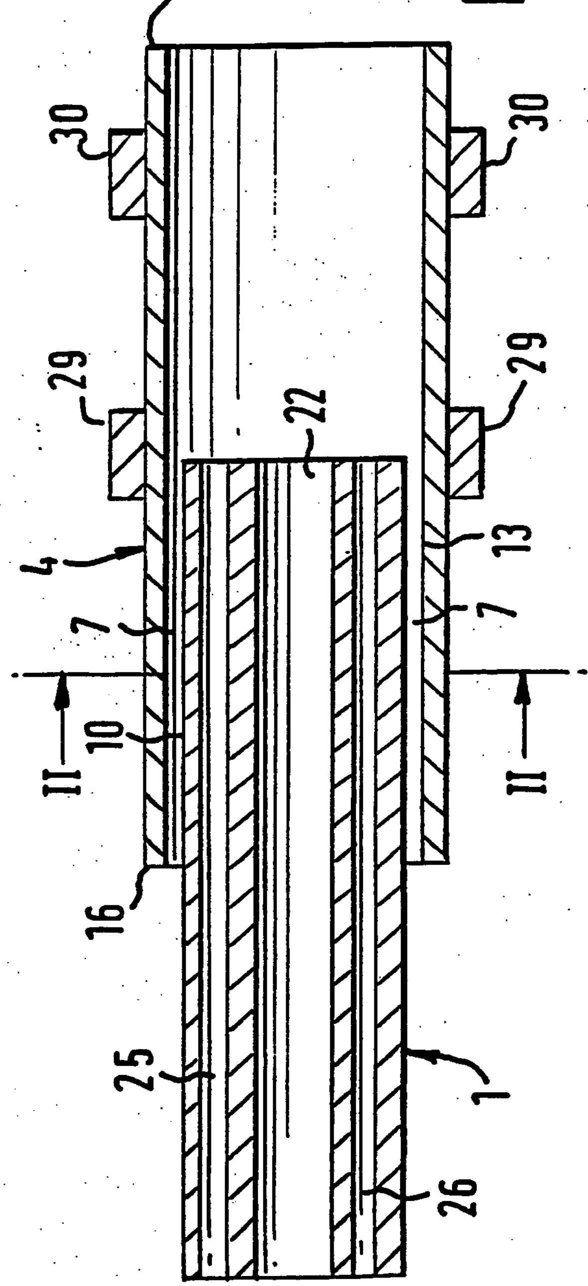


FIG.1

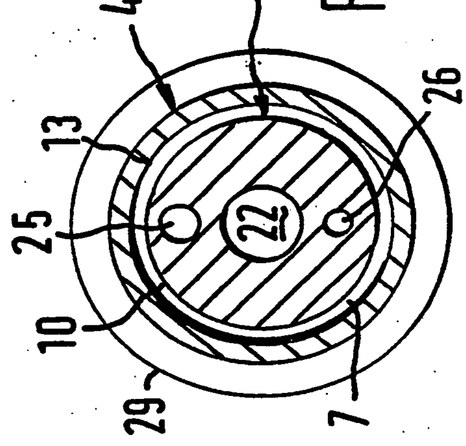


FIG.2

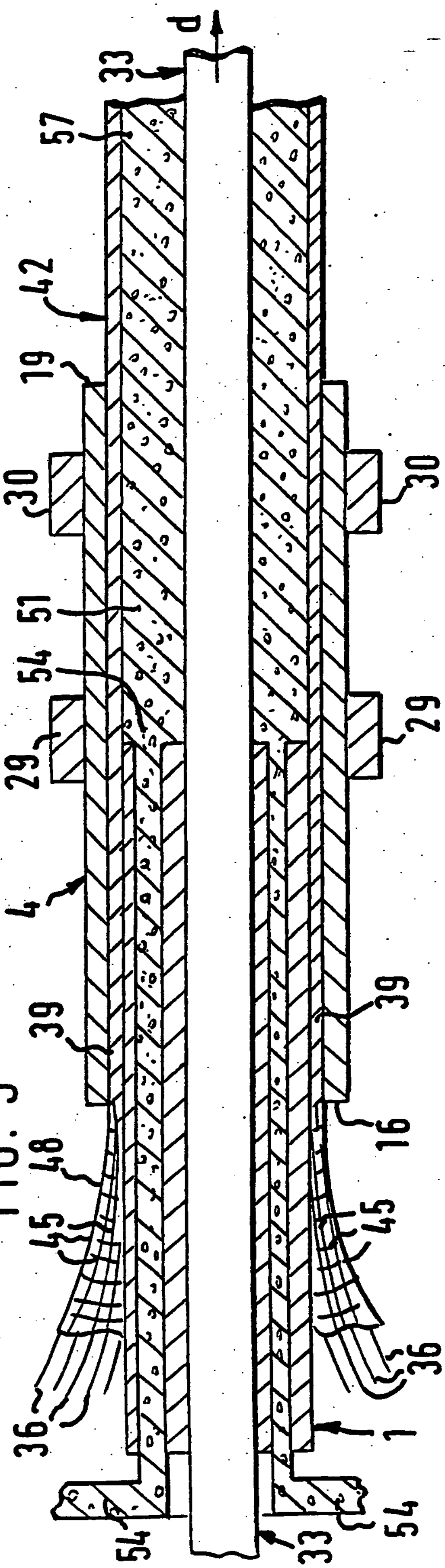


FIG. 3

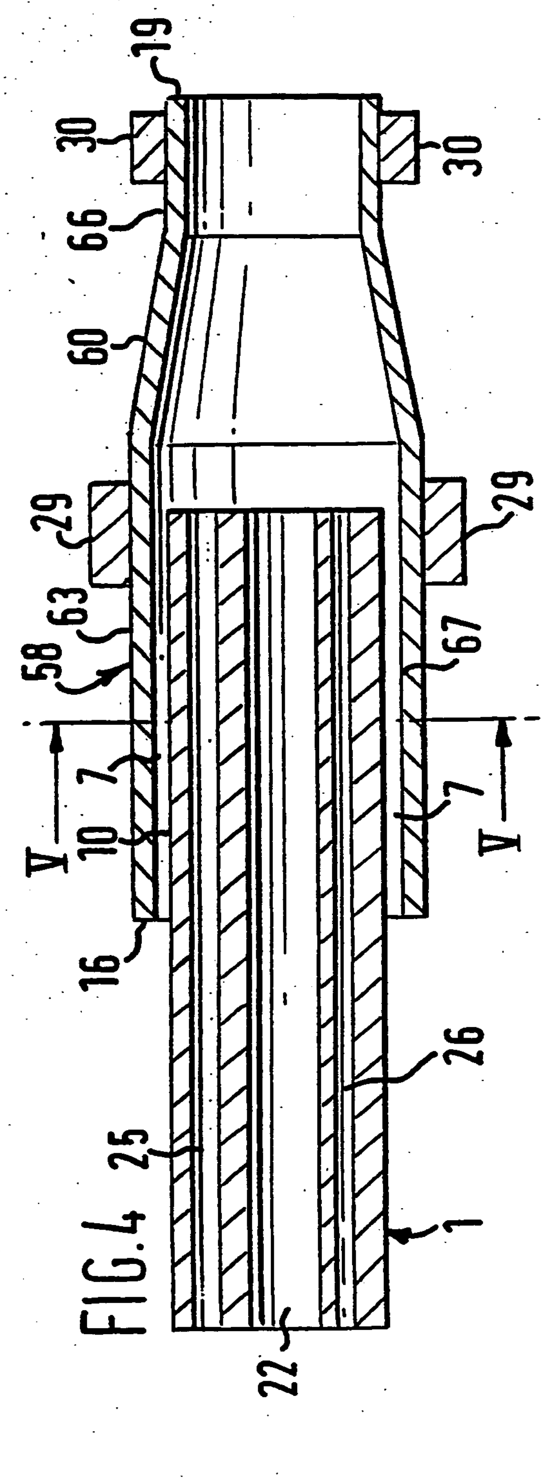


FIG. 4

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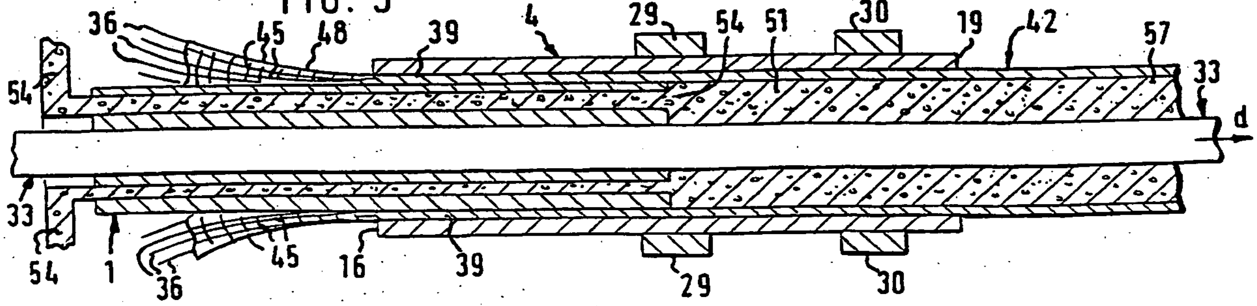

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EUROPEAN SEARCH REPORT

Application Number

EP 90 20 0121

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	GB-A-1 482 661 (RAKENNUSMUOVI OY) * The whole document *	1-2,4-5, 11,13-14	B 29 C 67/22 F 16 L 59/14 // B 29 L 23:22
X	DE-A-3 216 463 (G. NOACK) * The whole document *	1	
A	US-A-4 676 695 (F.C. DUTHWEILER) * Column 8, lines 43-61; claims 17,32,44; figure 2 *	1-14	
A	WO-A-8 704 768 (H.E. ERIKSEN) * Abstract; page 5, lines 1-31; claims 6-8; figure 1 *	1,3-5	
P,A	GB-A-2 210 316 (M.H. COLLINS) * The whole document *	2-5	
A	NL-A-8 502 032 (R.S. STUART-HOWIE) * Claims *	6-10	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

B 29 C 67
B 29 C 63
B 29 C 47

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	19 September 91	JENSEN K.S.

CATEGORY OF CITED DOCUMENTS

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